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Participant Assessments of Aviation Safety Inspector Training for Technically Advanced Aircraft

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NOTICE

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16. Abstract

Technically advanced "glass cockpit" aircraft are making their way into general aviation. Aside from technical challenges presented by learning any new system, pilots report some difficulty in acquiring a conceptual understanding of the functions offered by the avionics, developing system monitoring skills and habits, developing mode management and awareness skills, understanding when and when not to use automation, and maintaining manual flying skills. Operating aircraft with advanced avionics requires an additional set of knowledge elements and skills. Currently, Federal Aviation Administration (FAA) aviation safety inspectors are required to inspect technically advanced aircraft, check certified flight instructors, and conduct surveillance of designated pilot examiners who are certifying pilots operating technically advanced aircraft. Therefore, the FAA collaborated with researchers from National Aeronautics and Space Administration and Embry-Riddle Aeronautical University to develop and implement training for aviation safety inspectors on technically advanced aircraft. This paper reports initial participant evaluations of the course.

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PARTICIPANT ASSESSMENTS OF AVIATION SAFETY INSPECTOR TRAINING FOR TECHNICALLY ADVANCED AIRCRAFT

INTRODUCTION

Recently, there has been an emergence of technically advanced "glass cockpit" aircraft (TAA), within general aviation (GA). Fiduccia et al. (2003) defined TAA as aircraft in which the pilot "interfaces with computers to aviate, navigate and communicate," and as having, at a minimum:

a. IFR-certified GPS navigation equipment (navigator) with moving map; or
b. A multi-function display (MFD) with weather, traffic, or terrain graphics; and
c. An integrated autopilot (p. 9).

Much has been written about the introduction of TAA into commercial aviation (c.f., Dekker & Hollnagel, 1999). Billings (1997) described the introduction of the first generation of flight management computers (FMCs) on the Boeing 757/767 as a fundamental shift in aircraft automation. Chidester (1999) described a nearly 20-year process of change to policy, procedure, and training in the airline industry in response to human performance issues associated with this shift. Automated aircraft functions included integration of area navigation with performance management, computer guidance and control in four dimensions, and integration of warning and alerting systems for mechanical systems. These technological advances have begun to make their way into GA cockpits.

Operating aircraft offering advanced avionics differs from operating those with traditional analog instrumentation, simple autopilot functions, and reference to ground-based navigation. It requires an additional set of knowledge elements and skills. Aside from technical challenges associated with learning any new system, pilots report difficulties in acquiring a conceptual understanding of the functions offered by the avionics. Challenges include developing system monitoring skills and habits, developing mode management and awareness skills, understanding when and when not to use automation, and maintaining manual flying skills (FAA, 2005).

Lessons from the airline experience. Initial FMC aircraft in airline operations did not fully meet Fiducia et al.'s (2003) definition because they lacked satellite navigation and information acquisition. Nonetheless, Chidester (1999) described TAA introduced to the airlines as changing traditional flying tasks. Prior generations of aircraft allowed hand flying without flight director guidance or controlling the flight path by setting targets, such as rates of climb or descent or heading through a flight director or autopilot. TAA added capabilities to program a plan of flight in advance, including route of flight, speeds and altitudes at any point along the flight and, on some aircraft, time of arrival at a waypoint. TAA give pilots more options to accomplish the same task, often requiring a choice to optimize control and workload, in addition to making options possible that did not exist on previous generations of aircraft. Subsequent generations have also offered increasing levels of information to the pilot.

The introduction of TAA had some unintended consequences as well (Air Transport Association, ATA, 1998). The need to choose a level and mode of automation sometimes led to suboptimal choices. FAA (1996) described an undesirable tendency to attempt to correct an "automation-induced" deviation by manipulating the automated system rather than aircraft controls. Ewell and Chidester (1994) suggested that having more available choices among modes and levels produces at least the appearance of reduced standardization on TAA – as one observes across pilots and crews, one sees variation in selection of modes and levels among acceptable techniques.

Automating a strategic flight plan rather than short-range targets has sometimes led to pilots failing to detect and correct anomalous autopilot performance. Sarter and Woods (1995) identified a range of situations where crews were surprised by actions taken or not taken by their autoflight system. These were not detected through system annunciations but only through subsequent anomalous performance of the aircraft.

Navigating via waypoints defined only by latitude and longitude and referenced through navigation databases has sometimes led to errors and non-compliance with procedures defined by ground-based navaids. ATA (1998) described occasional nonconformance by TAA from these departure, arrival, and approach procedures and the need for pilots to confirm they are complying with the charted procedure for which they are cleared.

Predictably, air traffic procedures designed to accommodate less-capable aircraft can create complications for the pilot of an advanced aircraft (ATA, 1998). For example, a runway change in the terminal area is not amenable to quickly reprogramming the FMC. This can result in increased workload, distraction, and occasional error when resolved through that level of automation.

Billings (1997) has described the potential of operators to become disengaged from the underlying cognitive or physical processes that have been given over to automated systems. This leads to concerns over the maintenance of underlying skills which may be required in an abnormal or emergency situation. Chidester (1999) noted a surge in navigation deviations on aircraft formerly equipped with Omega Navigation Systems (which were decertified in 1997) but not yet equipped with a GPS replacement system:

> The source of these deviations was typically a failure of the pilot flying to tune and identify a new navaid, or select a new or correct radial on station passage, resulting in failure to make a required turn. Similar errors involving incorrect calculation of segment distances resulted in early course turns. These are basic functions of instrument navigation that were, until recently, assumed by [Omega Navigation Systems] coupled to the autopilot. When that function was removed, pilots had difficulty in reapplying a well-learned and understood process they had performed throughout their careers (p. 178).

Solutions to these issues in the airline environment required policy, procedure, and training development within airlines. Can we expect similar issues as these systems are introduced to GA? Will they be more extensive, given the experience and operational diversity of the GA community? What types of solutions will be required for GA?

Efforts in general aviation. Fiducia et al. (2003) reported conclusions reached by an expert team through review of accidents occurring on initial GA TAA and comparison of accident-involved aircraft and operator characteristics to those of non-TAA. Their study was part of the FAA/Industry Training Standards program and was precipitated by recognition that initial accident rates for the first GA TAA were not substantially lower than those for comparable non-TAA aircraft. Since these aircraft have newer capabilities, many designed to increase safety, lower rates had been expected. Reasons for this did not appear specific to TAA characteristics – TAA accidents involved both problems encountered when introducing any new technology and general pilot judgment issues common to non-TAA accidents in GA. Only one finding was unique to TAA, though in common with the airline experience: Programming an approach in the navigation interface during high-workload situations can distract from the primary duty of controlling the aircraft. The study team concluded that while TAA provide increased "available safety," obtaining it will require additional training to "exploit opportunities and operate within the limitations inherent in their TAA systems" (p. 6).

Casner (2005) added experimental evidence of potential unintended consequences of automation in GA TAA that are comparable to those in airline operations. TAA pilots flying a scenario in Visual Meteorological Conditions showed significantly degraded navigational awareness, which he hypothesized resulted from the passive role in en route navigation when the task is automated. He has also shown how that effect can be mitigated by interventions that re-engage the pilot in navigation, such as being tasked to find landmarks en route (Casner, in press a).

Fiducia et al. (2003) recommended that industry and FAA act to improve TAA training. This included general improvements in training methods and specific improvements for TAA system limitations and risk management. For the present study, their key recommendation was to coordinate implementation of improvements by all major players. Aviation Safety Inspectors (ASIs), the FAA personnel that interface most directly with the operators and pilots of TAA, are key players in this process.

Based on a series of experiments, Casner has produced training curricula (2003), textbooks (2002; 2001), and media (2003) to aid GA pilots in learning and understanding automated systems on TAA. For the present study, he provided curriculum guidance for pre-course materials and ground school for ASIs, based upon a TAA handbook concurrently in development (Casner, in press b).

ASIs and TAA. FAA aviation safety inspectors inspect aircraft, check certified flight instructors, conduct surveillance of designated pilot examiners (DPE) who, in turn, certify pilots, and participate in accident investigations. As TAA have been introduced to general aviation, ASI responsibilities have grown to cover their advanced systems. However, many, perhaps most, ASIs completed flight training prior to the entry of advanced avionics into GA. Unless they have independently pursued ratings on TAA, ASIs find themselves in uncharted territory when conducting an inspection or checkride. ASIs need to be knowledgeable of the capabilities, limitations, and the normal and emergency operating procedures in these aircraft so that they may safely and competently perform their inspection, checking, and surveillance function for operators using these aircraft. Importantly, ASIs must be prepared to recover and safely land the aircraft in the event of a serious deficiency or incapacitation of a pilot being checked.

Standard procedures for checking proficiency based upon traditional aircraft may not work in TAA. For example, simulating failures during an evaluation flight is not as straightforward as in a traditional aircraft – Partial-panel evaluation cannot be accomplished by simply covering an instrument. Because of the interconnection among

navigational components, simulated failures may not produce the same effects on instrumentation and autoflight as real failures, so ASIs must check the specific aircraft manual to determine how to simulate a failure.

ASI course on TAA. To better support ASIs in their duties associated with TAA, the FAA has implemented qualification courses for technically advanced aircraft. Casner (in press b) provided curriculum guidance to Embry-Riddle Aeronautical University (ERAU), which finalized and delivered the training. Training consisted of a prerequisite study course (printed pre-course materials and an exam covering those materials) and a qualification course (8 days of on-site training at the university, composed of ground school and 10 to 12 hours of flight training).

The present authors provided survey materials to participants in these courses to independently assess course outcomes – to determine how effective participants found the course to be in training the skills necessary for ASIs responsible for overseeing operations of these aircraft. We developed and administered surveys to solicit ASI feedback concerning course contributions to their abilities to: a) assess the operation of TAA under normal and emergency procedures; b) administer flight checks using the features of these aircraft; and c) evaluate the display and control differences between various models of "glass cockpit" technologies.

METHOD

Twenty-eight ASIs completed surveys evaluating the Prerequisite Study and Qualifications Course for TAA conducted between October 2005 and July 2006. All completed the Prerequisite Study materials prior to completing the Qualification Course on-site training at ERAU. Eighty-five percent had no previous formal instruction on TAA, but 88% had some prior hands-on experience with these aircraft.

The prerequisite course provided an overview of three major TAA electronic flight systems used in GA. The evaluation course reinforced this knowledge and instructed ASIs in methods to evaluate pilots and DPEs that operate TAA. The course also allowed ASIs to meet the proficiency standards required to operate TAA. Participants were evaluated at the completion of the prerequisite course and on two occasions during the qualification course. The prerequisite course evaluation was an end-of-course open-book test. For the qualification course, participants completed a single-engine airplane check (testing their proficiency on TAA) and an end-of-course check of evaluation skills (testing their ability to safely conduct a check ride on TAA). Scores from the qualification course evaluations were not made available to the authors due to existing agreements with the workgroup on what information may be retained from employees completing training. Scores from the prerequisite test were available but could not be linked to survey responses.

ASI participants received a prerequisite course evaluation (Appendix A) and a qualification course feedback survey (Appendix B). The surveys addressed their perceptions of their proficiency as a result of the courses and course content. For the prerequisite course, participants rated the degree to which the course material was related to their job duties, how able they felt to explain symbols used for navigation and terrain on the multifunction display, and how prepared they felt to perform system failures in TAA. For the qualification course, participants rated how effective the course material was in preparing them for surveillance of TAA, how well the check-ride allowed them to demonstrate their proficiency, how well they felt they understood the human factors implications within TAA, and the extent of their understanding of simulating TAA system failures.

Participants were assured that the surveys were voluntary and that they could choose not to answer any particular question. The right to refuse to participate was inherent in the survey process, as participants only completed the survey if they chose to do so. The authors distributed 54 survey packets and received 28 returns, yielding a 52% response rate.

RESULTS

Prerequisite course. The survey included 15 items using a five-point scale with one indicating "strongly disagree" and five indicating "strongly agree." Items assessed the presentation of materials and their adequacy for preparing participants for key aspects of their ASI duties. Item content, means, and standard deviations are displayed in Table 1.

Ratings for all items were positive, averaging 4.27 for presentation and 4.20 for preparation. Written comments by ten participants focused primarily on areas of possible improvement including: better photographic reproduction, more emphasis on specific autoflight and cockpit systems, and inclusion of Web-links where additional reference material could be obtained.

Qualification course. The survey included ten items assessing the presentation of materials and their adequacy for preparing participants for key aspects of their ASI duties. Item content, means, and standard deviations are displayed in Table 2.

Ratings for all items were positive, averaging 4.56 for presentation and 4.55 for preparation on a five-point scale. Written comments from 19 participants included commendations for the course instructors and designers on the

Table 1 – Assessments of the Prerequisite Course.

	Mean	SD
Course presentation	**4.27**	
The prerequisite course was related to ASI job requirements regarding TAA.	4.50	0.51
The prerequisite course material was relevant to the stated objectives of the course.	4.43	0.50
The prerequisite information was beneficial to learning.	4.36	0.49
The prerequisite exercises/scenarios were beneficial to learning.	4.15	0.60
The prerequisite course materials were clear and understandable.	3.93	0.66
The lessons were presented in a well-organized, logical order.	4.22	0.64
Preparation	**4.20**	
I am prepared to identify TAA system failures	4.15	0.60
I am prepared to describe the human factors considerations associated with TAA.	4.15	0.60
I am prepared to explain how basic flight information is displayed on a PFD.	4.50	0.51
I am prepared to explain the symbols used for navigation on the MFD.	4.21	0.69
I am prepared to explain the symbols used to depict terrain and topography on the MFD.	4.29	0.66
I am prepared to explain the weather display features available on the MFD.	4.18	0.67
I am prepared to explain engine and system display functions.	4.36	0.56
I am prepared to explain the use of electronic checklists, both normal and emergency.	3.75	0.89
I understand how to simulate a failure of each of the major components of a TAA.	4.21	0.69

Table 2 – Assessments of the Qualification Course.

	Mean	SD
Course presentation	**4.56**	
The information covered during the classroom instruction was related to ASI job requirements regarding TAA.	4.66	0.48
The student guide provided during classroom instruction was beneficial to learning.	4.45	0.57
The classroom exercises/scenarios were beneficial to learning.	4.48	0.63
The lessons were presented in a well-organized, logical order.	4.55	0.69
The instructor(s) provided adequate feedback regarding my classroom performance.	4.66	0.48
Preparation	**4.55**	
The training was effective at preparing me for surveillance of TAA.	4.55	0.57
My check ride allowed me the opportunity to demonstrate my proficiency regarding TAA.	4.59	0.57
I understand how to simulate a failure of each of the major components of a TAA.	4.59	0.57
I understand the human factors considerations associated with TAA.	4.55	0.57
I am prepared to perform duties as an ASI regarding TAA.	4.48	0.69

quality of the course and suggested areas for improvement: facility characteristics, opportunity to fly more instrument approaches, more emphasis on human factors concerns, and opportunity to fly multiple TAA types.

Six items were comparable between the prerequisite and qualification course surveys. Two-tailed, correlated t-tests comparing qualification to prerequisite ratings for these six items revealed four to be significantly different. The qualification course was more highly rated for the benefit of exercises to learning ($t(26)=2.36$, $p<.05$), being well organized ($t(26)=3.70$, $p<.05$), providing an understanding of human factors considerations ($t(26)=2.80$, $p<.05$), and understanding how to simulate a failure of each of the major components ($t(27)=3.04$, $p<.05$). This suggests that classroom and flight training provided additional utility beyond a distributed study guide.

DISCUSSION

The research questions prompting this study focused upon whether the prerequisite and qualification courses could provide the knowledge and skills needed to operate and administer flight checks on TAA, with a special emphasis on their displays and controls. Feedback from participants suggests that the courses did this very well – the ratings were highly positive and written comments were very favorable. Participants indicated that the courses had prepared them for their surveillance responsibilities. We must stress, however, that we did not have access to test scores from the course in a manner that allowed assessment of training effects on performance. Our efforts were research oriented, intended to assist course designers in determining whether their efforts were of value to participants and allowing them to make the case for a permanent course, if warranted. As the course undergoes formal evaluation, such performance assessments will be needed.

Extension of the course to all GA ASIs over the next several years could contribute to meeting recommendations by Fiducia et al. (2003) that industry and the FAA act to improve TAA training and coordinate implementation by all major players. ASIs interface directly with the operators and pilots of TAA and are essential to this process.

Further motivation to pursue this type of training may lie in the pre-training demographics of participants. Eighty-eight percent reported some prior hands-on experience with TAA, but 85% reported no previous formal instruction. That likely narrowed the focus of their feedback concerning operations they inspected. Providing good TAA training to this population offers great opportunity to improve the operations of TAA throughout general aviation.

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APPENDIX A

TAA Prerequisite Study Course (#18803)

The purpose of this training course was to provide you with an overview of three major TAA electronic flight systems used in general aviation. Please rate your satisfaction with course 18803 by indicating the degree to which you agree with each of the following statements about the course. Indicate your response by completely darkening the bubble corresponding to your answer.

Course Evaluation	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
1. The prerequisite course material was related to ASI job requirements regarding TAA. --	O	O	O	O	O
2. The prerequisite course material was relevant to the stated objectives of the course. --	O	O	O	O	O
3. The prerequisite information was beneficial to learning. ----------	O	O	O	O	O
4. The prerequisite exercises/scenarios were beneficial to learning. ---	O	O	O	O	O
5. The prerequisite course materials were clear and understandable.--	O	O	O	O	O
6. The lessons were presented in a well-organized, logical order.-	O	O	O	O	O
7. I am prepared to identify TAA system failures. --------------------	O	O	O	O	O
8. I am prepared to describe the human factors considerations associated with TAA. ---	O	O	O	O	O
9. I am prepared to explain how basic flight information is displayed on a PFD. --	O	O	O	O	O
10. I am prepared to explain the symbols used for navigation on the MFD. --	O	O	O	O	O
11. I am prepared to explain the symbols used to depict terrain and topography on the MFD. --	O	O	O	O	O
12. I am prepared to explain the weather display features available on the MFD. --	O	O	O	O	O
13. I am prepared to explain the engine and system display functions. ---	O	O	O	O	O
14. I am prepared to explain the use of electronic checklists, both normal and emergency. --	O	O	O	O	O
15. I understand how to simulate a failure of each of the major components of a TAA. ---	O	O	O	O	O

29280

TAA Prerequisite Study Course (#18803)

Demographics

	No	Yes
16. Did you participate in the Cirrus familiarization course at UND?	O	O
17. Have you had any prior formal training with TAA?	O	O
18. Have you had prior hands-on experience with TAA (i.e., glass cockpit, GPS)?	O	O

If yes, what type of experience and when?

____

The following information is optional.

Name — Reporting FSDO

First — Last — (e.g., SW15)

Additional Comments

Please use the space below to provide any additional comments you may have about the course.

Please return your completed questionnaire in the business-reply envelope provided or mail to:

Aerospace Human Factors Division (AAM-500)
TAA Evaluation
PO Box 25082
Oklahoma City, OK 73125

Thank you for your participation!

29280

APPENDIX B

Qualification for TAA Course (#18830)

Recently, there has been an emergence of technically advanced aircraft (TAA), "glass cockpit", within general aviation. Operating aircraft with advanced avionics requires an additional set of knowledge elements and skills. The purpose of this training was to provide you with the knowledge and skills necessary to perform TAA pilot certification checkrides, oversee TAA designated pilot examiners, and conduct 709 evaluation flights in TAAs. Please rate your satisfaction with course 18830 by indicating the degree to which you agree with each of the following statements about the course. Indicate your response by completely darkening the bubble corresponding to your answer.

Course Evaluation	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
1. The information covered during the classroom instruction was related to ASI job requirements regarding TAA.	O	O	O	O	O
2. The student guide provided during classroom instruction was beneficial to learning.	O	O	O	O	O
3. The classroom exercises/scenarios were beneficial to learning.	O	O	O	O	O
4. The lessons were presented in a well-organized, logical order.	O	O	O	O	O
5. The instructor(s) provided adequate feedback regarding my classroom performance.	O	O	O	O	O
6. The training was effective at preparing me for surveillance of TAA.	O	O	O	O	O
7. My checkride allowed me the opportunity to demonstrate my proficiency regarding TAA.	O	O	O	O	O
8. I understand how to simulate a failure of each of the major components of a TAA.	O	O	O	O	O
9. I understand the human factors considerations associated with TAA.	O	O	O	O	O
10. I am prepared to perform duties as an ASI regarding TAA.	O	O	O	O	O

Demographics	No	Yes
11. Did you participate in the Cirrus familiarization course at UND?	O	O
12. Did you complete the prerequisite course 18803 introducing you to TAA?	O	O
13. Have you had any prior formal training with TAA?	O	O
14. Have you had prior hands-on experience with TAA (i.e., glass cockpit, GPS)?	O	O

If yes, what type of experience and when?

27897

Qualification for TAA Course (#18830)

The following information is optional.

Name | Reporting FSDO

First | Last | (e.g., SW15)

Additional Comments

Please use the space below to provide any additional comments you may have about the course.

Please return your completed questionnaire in the business-reply envelope provided or mail to:

Aerospace Human Factors Division (AAM-500)
TAA Evaluation
PO Box 25082
Oklahoma City, OK 73125

Thank you for your participation!

27897